New generation IoT-based healthcare applications: Requirements and recommendations

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***Abstract*—** Internet of Things (IoT) and healthcare are two valuable application requirements in the emerging 5G mobile networks. In a broad sense m-health represents the delivery of healthcare services through mobile devices, the function of which is to capture, analyze, store and transmit health information from multiple sources, including sensors and other biomedical acquisition systems. Solutions based on e/m-health decrease medical errors improving at the same time the efficiency health services and reducing operating costs. This paper surveys IoT for healthcare together with services and applications, security and technologies for promoting the corresponding services. In addition, this paper is going to invoke 5G network technology and health IoT including Internet of medical things. Next, current standardization activities and recommendations are outlined. Proposals for the future work conclude the presentation.

***Keywords*—**Internet of medical Things, 5G requirements.

I. Introduction

IoT has been widely studied and applied in many fields. The main reason for this fact is the possibility for providing human-to-human (H2H), human-to-machine (H2M) and machine-to-machine (M2M) communications. The IoT incorporates transparently a large number of different and heterogeneous end systems, while providing open access to selected data for the development of digital services. Thus, building an architecture for the IoT is a complex task, concerning variety of devices and services to be involved in such a system. Healthcare applications impose rigorous requirements on system reliability, quality of service (QoS) and security [1, 2].

Internet of medical Things is a challenging environment due to the high number of heterogeneous and potentially constrained network devices and heavy traffic pattern. One of the characteristics of digital medicine is remote access to images and the ability to rapidly share information across geographic areas, compressing time and distance. Ease of cost-effective interactions through secure connectivity across patients, hospitals and healthcare organizations is an important task. Healthcare networks with wireless technologies are expected to support diagnosis and real-time monitoring.

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This paper structured as follows. We start with presenting IoT for healthcare. This section is composed of three parts. It highlights services and applications, security as well as appropriate technologies. Next section is going to describe 5G network technology together with health IoT. In connection with this, the contribution of Internet of medical thighs is pointed out. Standardization activities and frameworks, together with proposals for future work conclude the presentation.

II. IoT for healthcare

Starting from the potential of IoT-based healthcare technologies, a lot of experiments are carried out worldwide. The obtained results are optimistic in the domain of numerous applications, services and prototypes. Network architecture and platforms as well as interoperability and security are included, too. As initial IoT based healthcare technology, the wireless sensors networks (WSNs) are considered. The IP-based sensor networks using IPv6-based low-power wireless personal area network (6LoWPAN) are adopted [3]. IoT healthcare network is shown in Table 1 with topology, architecture and platform.

Table 1 An example of IoT healthcare network..

Topology	Architecture	Platform
physical configurations, application scenarios, activities, and use-cases	software organization of the system as a whole and hierarchical model reflecting	library, framework, and environment

The way a heterogeneous computing grid collects medical vital parameters such as blood pressure (BP), body temperature, electrocardiogram (ECG), oxygen saturation is shown in Fig.1. IoT network is formed while transforming into hybrid computing grids the heterogeneous computing and storage capability of static and mobile electronic devices such as medical terminals.

A. Services and applications

Services are used to develop applications, and are developer-centric. On the other hand, applications are directly used by users and patients and user-centric. Categorization concerning IoT healthcare services and applications is shown in Table 2.

Table 2. IoT healthcare services and applications categorization.

Services	Applications	
	Single-condition	Clustered-condition
Ambient assisted living Internet of m-health Adverse drug reactions Community healthcare Children health information Wearable device access Semantic medical access Indirect emergency healthcare Embedded gateway configuration Embedded context prediction	Clucose level sensing ECG monitoring Blood pressure monitoring Body temperature monitoring Oxygen saturation monitoring	Rehabilitation system Medication management Wheelchair management Imminent healthcare Smartphone healthcare solutions

Each service provides a set of healthcare solutions. Various types of services with different purposes are presented in Table 3.

Table 3. Variety of IoT healthcare services providing a set of healthcare solutions.

Services	Healthcare scenario
Ambient assisted living (AAL)	Extend the independent life of elderly individuals in a safe manner, giving them human servant-like assistance in case of any problem [5]
Internet of m-health things (m-IoT)	Mobile computing, medical sensors and communication technologies fir healthcare services. M-IoT uses connectivity model that connects the 6LoWPAN with 4G networks for future internet-based m-health services [6]
Adverse drug reaction	The patient's terminal identifies the drug by means of barcode enabled devices [7].
Community healthcare (CH)	Specialized service community healthcare (CH) is used for obtaining collective technical requirements as a package. Community medical network (virtual hospital) integrates multiple wireless body area networks (WBANs) to materialize CH [8].
Children health information (CHI)	IoT service called CHI is developed to address children with emotional, behavioral or mental health problem and their family members.
Semantic medical access (SMA)	IoT healthcare application employ medical rule engines to analyze massive amounts of sensor data stored in the cloud. The wide potential of medical semantics has received attention in designing IoT-based healthcare applications [9,10].
Indirect emergency healthcare (IEH)	Dedicated service called IEH can offer many solutions such as information availability, after notification, post-accident action, and record keeping.
Embedded gateway configuration (EGC)	The EGC service allows for automated and intelligent monitoring. For a medical sensor network based on the IoT a personal mobile gateway is employed [11].
Embedded cost prediction (ECP)	The ECP service is developed in the context of ubiquitous healthcare [12]. A context predictor is applied to IoT-enabled remote health monitoring.

B. Security

Iot healthcare domain may be a target of attackers because devices and applications are dealing with private information, presenting healthcare data. In order to obtain the full adoption if IoT for this goals, it is of crucial interest to identify security requirements, vulnerabilities, threat models as well as countermeasures. To achieve corresponding services, the focuses are on confidentiality, integrity, authentication, availability, resiliency, fault tolerance.

On the other hand, novel challenging tasks for secure IoT healthcare services include: computer limitations, memory limitations, energy limitations, mobility, scalability.

It is well known that threats may originate from both within and outside the network. As for an attacker, be can devise different types of security threats, just to make compromise between existing and future IoT, medical devices and networks.

C. Techniques for promoting services

Several technologies such as cloud computing, grid computing, big data, etc., have the potency to promote IoT-based healthcare services.

Cloud computing poses challenges such as high availability, load balancing high performance. Also, there is a possibility of extending cloud computing beyond data centers towards the mobile end-user, providing end-to-end mobile connectivity as a cloud service. The integration of cloud computing into IoT-based healthcare technologies should provide facilities with ubiquitous access to shared resources. In that way, offering services upon on request over the network and executing operations fir various needs are realized.

Grid computing is viewed to be the backbone of cloud computing. Including grid computing to the healthcare network, the insufficient computing capability of medical sensor nodes is addressed.

Big data, as the next step in computing, poses numerous challenges to the research community and needs collaborative vision and dialog from various fields including healthcare. It includes huge amount of health data which are generated from medical sensors. Tools for increasing the efficiency of relevant health diagnosis as well as monitoring methods and stores are provided, too.

The question often arises when speaking about network type appropriate for IoT-based healthcare, is an open issue. There are three different types of designing: data, service and patient-service architectures. In the data–centric scheme, the healthcare structure is separated into objects based on captured health data. On the other hand in a service-centric scheme, the healthcare structure is allocated taking into account characteristics that they must provide. Finally, in the patient-centric scheme, healthcare systems are divided according to the involvement of patients they considered for treatment.

III. 5G NETWORKS AND INTERNET OF MEDICAL THINGS

From first generation (1G) networks, to the current fourth generation (4G), the evolution of telecommunications technology has transformed how users share and consume information. Today, fifth generation (5G), creating a new era of communications, brings to the market contemporary patterns of connectivity. 5G of mobile networks will support a wide range of features and use cases, going well beyond current cellular networks. While increased capacity to support enhanced mobile broadband services is a key driver. 5G will be required to support ultra-reliable, low-latency and massive machine communications. 5G will cover wide range of frequency bands, ranging from bands below 6 GHz to millimeter wavebands. Also, 5G includes a heterogeneous network that integrates 4G, WiFi, millimeter wave and other access technologies. It combines cloud infrastructure, intelligent services and distributed computing model. Connected devices, fast and intelligent network, back-end services and extreme low latency are characteristics that distinguish 5G from its predecessors. In that way, mobile broadband, M2M communications, artificial intelligence and advanced digital devices are provided. The 5G era will allow people to have real-time health services which will become the society norm.

In today's mobile world, execution takes place in around 50-80 milliseconds. With the advent of 5G, the goal is to reduce that interval to a few milliseconds. For example, autonomous car technology, which allow a vehicle to navigate without human input, requires great speed in digital computation. Small delays from a vehicle sensors can give catastrophic results.

IoT is a challenging environment due to the high number of heterogeneous and potentially constrained network devices and heavy traffic pattern. It introduces a vision of a future Internet where users, computing systems and objects cooperate with convenience and economical benefits. One of the characteristics of digital medicine is remote access to images and the ability to rapidly share information across geographic areas, compressing time and distance. The healthcare system is enabled to overcome disparities not only based on geography, but also on income or class status. Owing to digital medical technology, health disparities will be reduced, while urban/rural difference that exists in most countries will be missing. Of course, if the diagnosis is not complicated, people can get medical help through video conferencing and telemedicine.

The billions of devices and sensors with 5G will make possible gathering of the data, doctors need about genetic composition, social environment and life style characteristics. While most computers lack sufficient storage for that details, storage the data on a cloud makes it available to doctors and researchers. The cloud provides the extensive storage capabilities that doctors need in order to obtain advantage of these latest developments. To ensure appropriate treatment for each patient, interoperable devices work together with intelligent notification systems.

IV. STANDARDIZATION ACTIVITIES AND FRAMEWORKS

In healthcare, interoperability facilitates the capability to exchange health data between different information technology systems and software. Standards should permit data sharing between providers, diagnostic labs, pharmacies, and patients regardless of the application or vendor. International organizations such as Bluetooth SIG, USB Implementers Forum, IHE, IEEE and HL7 publish specifications, profiles and standards for health data interoperability. The IEEE 11073 Personal Health Data (PHD) family of standards is intended to support interoperable communications for personal health devices, and convey benefits such as reducing clinical decision-making from days to minutes, reducing gaps and errors across the spectrum of healthcare delivery and helping to expand the potential market for the medical devices.

IoT researchers work together with versions m-health and e-health organizations as well as standardization bodies such as the ITIEF (Information Technology and Innovation Foundation), IPSO (Internet Protocol for Smart Objects) alliance and ETSI (European telecommunications Standard Institute) to form IoT technology working groups for the standardization of IoT-based healthcare services. The standardization considers a wide range of topics such as communications layers and protocol stacks. Physical (PHY) and media access control (MAC) layers, device interfaces, data aggregation and gateway interfaces are included, too. One of the advantages of the Internet has been flow of data and trade across borders. This has been facilitated by international agreement of experts, at the same time identifying the most promising technologies to get them adopted on a widespread basis. Maintaining data sharing networks and exchange of trusted information is vital for 5G and the IoT. On the other hand, application developers need open standards and a clear computational architecture in order to have international interoperability.

IEEE 802.16 (WiMax) is a good choice for telemedicine service providers not only in mobile, but also in a fixed environments. The advantages are transmission speed, security, mobility and QoS [13]. Radiology and ultrasound images can be transmitted with significantly reduced delay through the high bandwidth. With a large network capability, some monitoring and diagnostic processes are performed simultaneously. Also, QoS increases the efficiency and reliability of data transmission. The IEEE 802.16 MAC fits with health applications that are designed to be unobtrusive with QoS requirement. In this case, the integration of low rate wireless private area network and a wireless mesh backbone represents wireless solution for delivering medical services in real-time.

IEEE 802.15 (WPAN) wireless personal area network is the standard covering link technologies between data collectors and wireless sensors for healthcare application [14]. ZigBee-based WSNs are for use in acute care hospitals and beyond. A disadvantage is that its low bandwidth of 250 Kbps increases the tames it takes to send the same amount of data by up to 4 times compared to Bluetooth LowEnergy, which is an avoidable candidate among low-power access technologies.

Body sensor networks (BSN) is a type of WSN. It is deployed on human body to getter physiological parameters for health purposes [15]. Shorter communication range, more limited computation capability and data rate, more sensitive data, higher safety regulation requirements for specific absorption rate, etc., are the unique characteristics compared to majority of general wireless personal area networks. IEEE developed its typical enabling technology IEEE 802.15.6-2012, although it can not meet some desired requirements such as reliability.

V. Concluding Remarks

Recent trends in IoT-based healthcare go to the direction how clinical research is conducted while disease therapies are delivered. In this sense, various aspects of IoT-based healthcare technologies are supported, together with network architecture and technologies in order to ensure medical data transmission and reception. Taking into account industry trends and following technologies, a broad view on how advances in devices, sensors, Internet applications, have got influence on healthcare services and security, is of wide interest. The motivation is to expand the potential of IoT-based healthcare services for future developments. The use of mobile devices, sensors and remote monitoring equipment is going to grow every day providing advancement in patients receiving imaging diagnosis or treatment using digital technology. A lot of works used to be done to facilitate end-to-end system with interoperable and secure devices. Also, as an important issue, standardization is expected to facilitate a basis for further research on IoT-based healthcare services. This will significantly reduce healthcare and hospitality costs.

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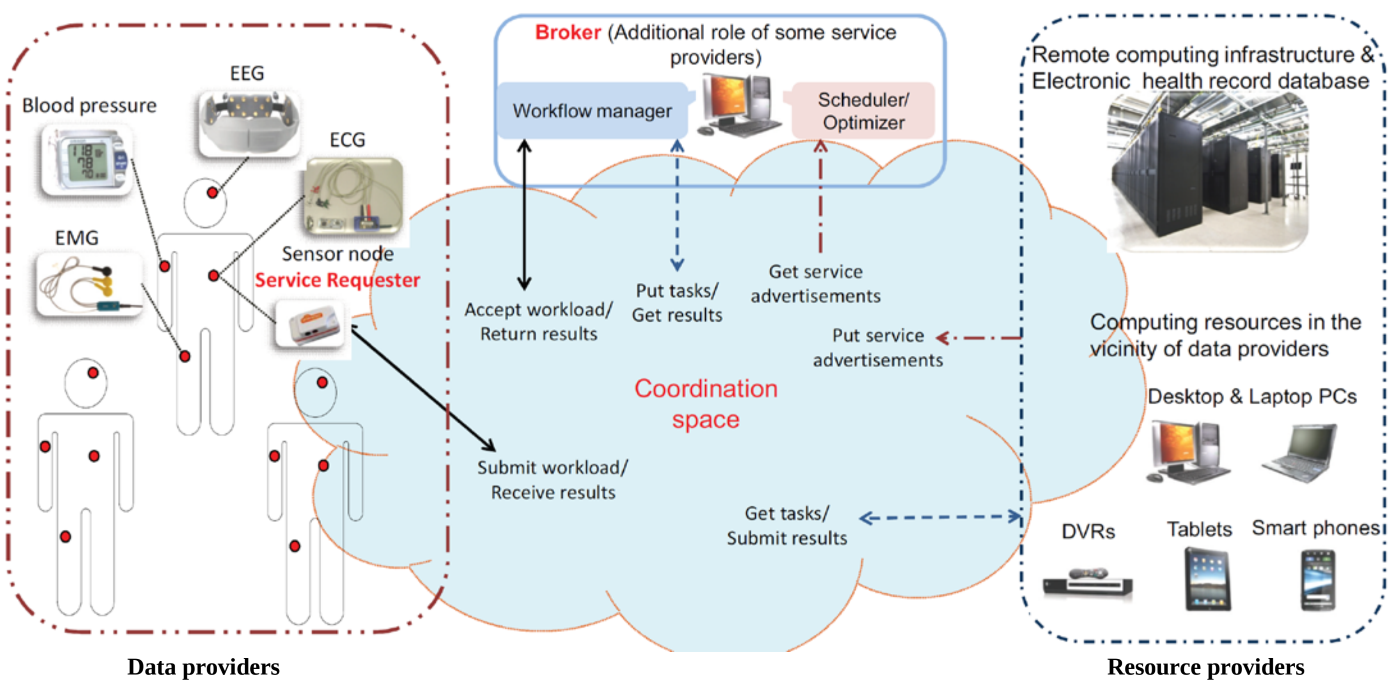

Fig. 1 IoT-based healthcare solution [4].